

Diagnostics Based on Short-Term Monitoring.

By

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Diagnostics based on short-term monitoring is the application of specialized software and hardware tools to systematically gather and analyze data typically over a two week period to evaluate the performance of building energy systems, such as HVAC, controls, and lighting.

This paper and presentation will show how diagnostics based on short-term monitoring can clarify your understanding of how the systems in a building actually perform. The data analysis results allow you to make decisions with the confidence of knowing how systems are actually performing or clearly knowing what is actually broken, rather than the uncertainty of making decisions without performance facts. For this reason, short-term monitoring data provides the information needed to say, “I know” vs. “I think.”

Buildings are individuals. No two are exactly the same and the ailments of one are not identical to the ailments of another. Even if they were built at the same time from the same plans and have the same mechanical and lighting equipment, buildings are used differently, are operated differently, have been serviced differently, and will have different problems. They need to be treated as individuals, just as people are. A doctor would never say, “Your twin brother was here yesterday and needs open heart surgery. We think you need open heart surgery too. How does next Thursday sound?” My first reaction would be, “Doc, that’s crazy. My brother eats fatty foods, is 40 pounds overweight, and never exercises. He smokes two packs a day and hasn’t taken a day off work in three years. He doesn’t take care of himself like I do. You don’t know that I have problems. How can you recommend surgery for me without performing diagnostic tests? Don’t you want to do an EKG, X-ray, MRI or some other kind of test?”

We are familiar with the concept of short-term monitoring as it applies to medical diagnostics. The same concept applies to buildings. We can use short-term monitoring to collect the data to perform diagnostics. Just like an EKG, X-ray, or MRI equipment, the monitoring equipment doesn’t have to be permanently installed. Medical tests are typically run over a relatively short period of time. Building diagnostics, based on short-term monitoring, are the best way to gain an understanding of the performance of a building’s systems, to pinpoint problems, and to identify the existence of problems requiring further investigation.

Why do buildings need diagnostics based on short-term monitoring? Most buildings have energy management systems and receive maintenance on a regular basis. The energy management systems are there to control the equipment and the service keeps it running in tip top condition, right? Not exactly. If both of these were true, we’d never see the constant increase in operating costs that occurs in the majority of buildings. The fact of the matter is that control systems are not always programmed properly, don’t

maintain calibration forever, don't always control all the equipment in a building, and may have been modified over time. Also, periodic service is typically not comprehensive enough to maintain equipment at its peak performance. Emergency service almost always results in "changes" made to equipment to solve the problem reported that day. Over time these changes can do more harm than good. Diagnostics based on short-term monitoring can reveal and unravel problems created over time that would be very difficult to identify in a typical service call. The premise is that by looking at graphs that represent key relationships of how the system operates over time, operating efficiencies can be clearly identified. For example, the graph below (Figure A) represents an economizer that was never operating, resulting in missed free cooling opportunities.

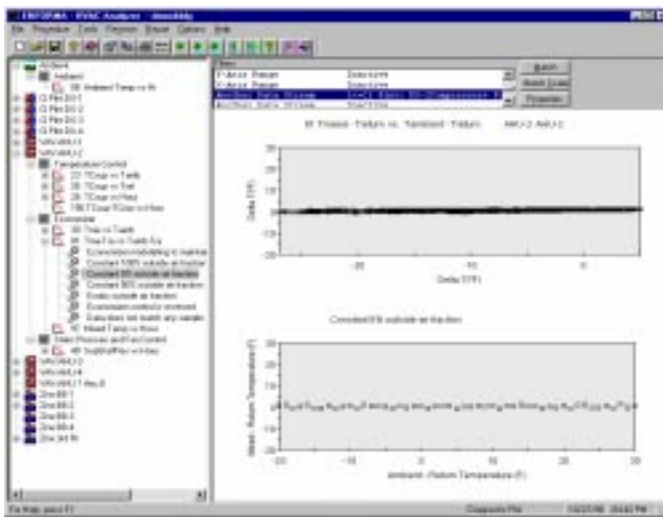


Figure A - Economizer Diagnostic Graph

Architectural Energy Corporation conducts short-term monitoring using battery-powered data loggers and specialized software. We developed a line of monitoring equipment called the MicroDataLogger® portable data acquisition system specifically for monitoring building systems. We did this because there wasn't a product on the market flexible enough to monitor any required parameter. Our equipment is designed to allow the snap on adaptability to measure any building parameter on any channel of our four-channel logger including temperature, relative humidity, current/power, pressure, air flow, any standard output signal, and lighting parameters. The bottom line is one logger will measure different types of parameters that may be right next to each other.

Another key feature is that the battery in our logger supplies voltage to sensors that need it to operate. We did this so the equipment can be installed quickly. Why require a 120 volt outlet to plug a transformer into to create 12 volts DC to power a humidity sensor or flow sensor. By drawing directly from the battery in the data logger, the installation is simpler and faster. Our battery is designed to run long enough to collect the data needed for short-term monitoring in buildings.

The short-term monitoring process is divided into three steps: project planning, measurement of system data, and data analysis. The objective of the planning step is to establish the data streams that need to be collected by the data acquisition equipment. The person responsible for the diagnostic activity conducts all the tasks necessary to determine what measurements should be made and prepares the monitoring equipment. The activities in this process include:

- ◆ State the goals and objectives of the monitoring and diagnostic processes, including any “data products” required,
- ◆ Obtain copies of mechanical plans and specifications, including control drawings and sequences of operation,
- ◆ Tour the building with the operations staff to gather information about the building and its systems,
- ◆ Interview operations staff to discuss obvious or chronic problems, operating and occupancy schedules, operation of the EMS, and any other information they can provide,
- ◆ Determine the methods that will be used to analyze the data,
- ◆ Develop a list of data requirements based on the plans and building tour and determine where all the measurements will be made in the building,
- ◆ Assemble the data loggers and sensors, and
- ◆ Program the data loggers.

The objective of the measurement step is to collect the data needed for the analysis. The building should be operated in a normal manner during the monitoring period. The activities in this process include:

- ◆ Install data acquisition equipment in the building (central plants, systems, and zones),
- ◆ Verify the correct operation of all equipment,
- ◆ Operate the building in a normal manner,
- ◆ Retrieve the loggers and sensors at the completion of the monitoring period, and
- ◆ Patch holes and restore the site to the condition it was found.

The objective of the data analysis step is to understand the operation of the systems. Systems working properly and ones operating inefficiently will be identified in this process. The activities in this process include:

- ◆ Download the data from the loggers to the computer,
- ◆ Use software-based automated analysis tools or spreadsheets to create the graphs needed to detect problems, and
- ◆ Calculate the energy and cost savings that can be achieved through repairs, modifications, and equipment replacements.

AEC has developed a software/hardware solution designed to automate many of the processes just described in short-term monitoring. The specialized software we use is called the ENFORMA® Portable Diagnostic Solutions. We have both an HVAC

Analyzer application and a Lighting Analyzer application. Both of these are designed to prompt the user through the processes of planning a project, getting ready for data collection, downloading data, and analyzing data.

During the planning stage, the ENFORMA Portable Diagnostic Solutions software automatically develops the list of required measurements based on a description of the HVAC or lighting equipment in the building. The MicroDataLogger loggers connect to the computer via the serial port, and the software programs each of the data loggers based on the plan and synchronizes their clocks so they all gather data at the same time. The software keeps track of each data logger's serial number and the measurements assigned to each channel of each logger in order to insure that no key data streams are missed. The MicroDataLogger system is designed to be easy to install and remove in order to keep the costs at a minimum. Experienced and qualified professionals always handle the responsibility of installing sensors on electrical equipment.

The ENFORMA software uses the collected data to automatically calculate parameters such as temperature difference, enthalpy, and power. It then displays plots of the performance data. For each performance plot it displays an example plot for a correctly operating system and examples for systems with possible problems. The operator matches the actual plots with the examples until the best match is identified. This match describes the problem with the system. There are also powerful data filters that allow the user to quickly perform "what if" diagnostics on the various systems. Potential energy savings (or energy wasted) over the monitoring period can often be easily calculated, or simulation software can be used to calculate savings for a season or the entire year.

AEC has been developing the process implemented by the ENFORMA software and MicroDataLogger equipment for many years. We filed a patent application on it long before others were thinking of using battery-powered logging devices with analysis software to perform diagnostics. U.S. Patent No.5,481,481 was issued in January 1996. The patent covers the use of more than one data logger, at least one of which is wireless, to monitor systems with operationally interdependent components that are spaced far apart where the data are time synchronized and input to a computer for analysis. This patent covers diagnostics on HVAC and lighting systems, as well as other applications.

The following types of HVAC equipment can be tested with the ENFORMA system:

- ◆ Air distribution systems
 - Air handlers
 - Economizers
 - Humidifiers
 - Evaporative coolers

- ◆ Plants
 - Boiler
 - Chiller
 - DX systems
 - Cooling towers
 - Heat pumps
 - Thermal energy storage
- ◆ Zones
 - Temperature
 - Humidity
 - Terminal systems
- ◆ Controls
 - Basic functionality
 - Schedules
 - Sequence of operation

Listed below are categories showing the types of HVAC diagnostics performed using the ENFORMA system. Examples of problems that can be identified within each category are provided.

- ◆ Schedules
 - Equipment operating at night, weekends, or other times when it is assumed to be off.
- ◆ Setpoints/temperature control
 - Occupied spaces maintained above or below setpoints.
 - Systems, such as chilled water or supply air, operating above or below setpoints.
- ◆ Sequence of operation of individual equipment
 - Outside air dampers not modulating on economizers.
- ◆ Interaction between different pieces of equipment
 - Simultaneous and unintended operation of heating and cooling equipment.
- ◆ Cycling
 - Excessive compressor cycling.
- ◆ Capacity and flow rates
 - Insufficient cooling capacity.
 - Insufficient air flow

Listed below are categories showing the types of lighting analyses performed using the ENFORMA system. Examples of problems that can be identified within each category are provided.

- ◆ Controls (manual and automatic)
 - Lighting equipment operating at night, weekends, or other times when it is assumed to be off.

- ◆ Lighting retrofit savings
 - Measure pre and post lighting load shapes and determine total savings.

The following case study clearly illustrates the value of diagnostics based on short-term monitoring.

Building information

Building type: 4 story office building in Baltimore, Maryland

Building size: 60,000 square feet

Year built: 1987

HVAC System:

Cooling provided by 8 Carrier rooftop units:

Six 20-ton

Two 25-ton

Heating provided by zone electric baseboards.

Systems metered for this project:

To get a clear picture of how the cooling, heating and lighting systems were operating in the building over time, the following systems were metered based on a plan created by the ENFORMA HVAC and Lighting Analyzer software.

- 4 rooftop units (total electric power and air stream temps)
- 2 rooftop units (air velocity and pressures)
- Electric baseboard heater circuits (current)
- Lighting circuits (current)
- Zone and ambient temperatures

Results of diagnostic testing

- Rooftop units were running well past the expected schedule including late evening and Sunday operation.
- 3 out of 4 rooftop units measured did not have an operating economizer (see Figure A).
- AC Compressor comes on at 46°F outside air temperature
- AC Compressor and electric baseboard heat were heating and cooling the same space at the same time (see Figure B below).
- 50% of the lights are on all night.

Benefits Summary

- Found the potential for over a 17% reduction in energy costs for HVAC and lighting by fixing operational issues and upgrading equipment.
- Cost effectively supplied the data needed to perform accurate HVAC tune-ups.
- Provided a visual summary of system performance that clearly justifies the need for equipment upgrades.
- Raised the capability level of the building technician by using a standard integrated approach for building diagnostics.

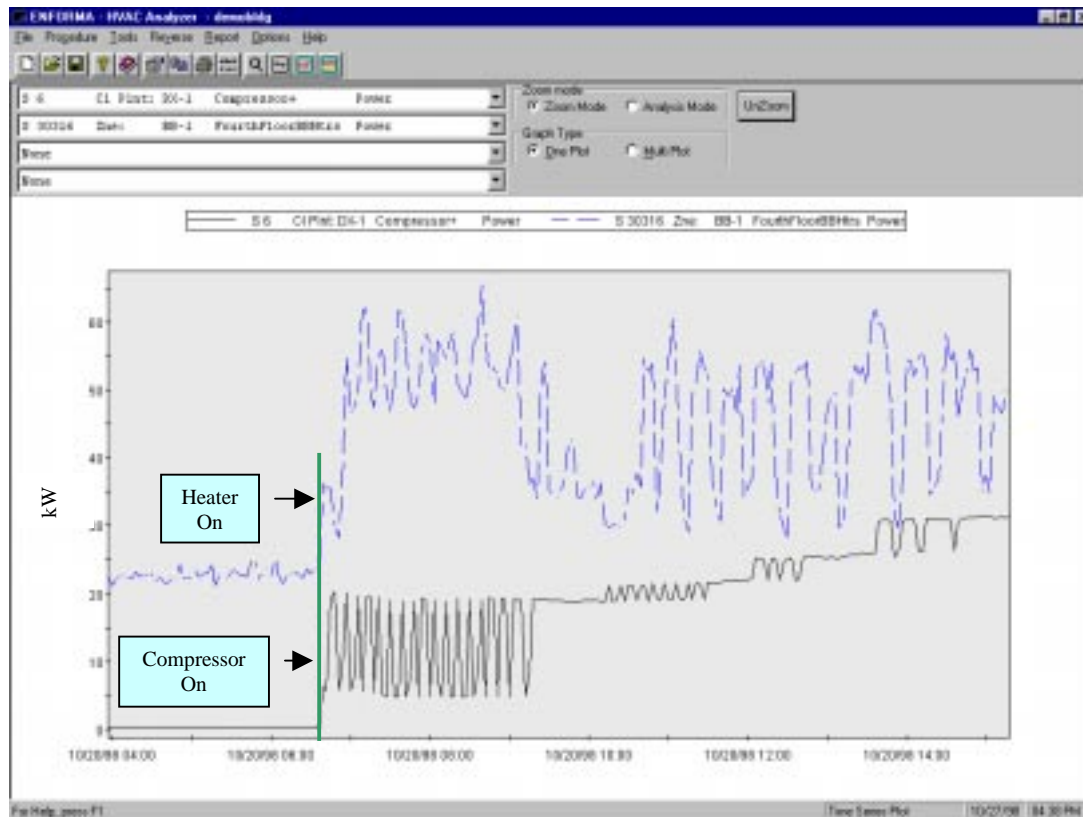


Figure B – Diagnostic graph showing simultaneous heating and cooling